UNIVERSITI PUTRA MALAYSIA

EVALUATION OF MOTORCYCLE SEAT WITH LUMBAR SUPPORT MASSAGER IN REDUCING DISCOMFORT AND MAINTAINING SPINAL POSTURE AMONG TRAFFIC POLICE RIDERS

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June 2021

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Traffic police riders are exposed to prolonged static postures causing significant angular deviation of the musculoskeletal, including the lumbar angle (L1-L5). This postural alteration contributes to muscle discomfort, especially in the lower back area, as it is one of the most severe modern diseases nowadays. Discomfort due to riding a motorcycle is an issue that needs to be addressed as it has long-term effects of musculoskeletal disorders (MSD) on motorcycle riders, especially among occupational groups. Thus, this study aims to evaluate lumbar support with a built-in massager system in order to reduce discomfort among traffic police riders. The first stage of this research examines the ergonomic problems experienced by the riders using a valid motorcycle seat discomfort survey, body chart discomfort, extensive literature search and prior patent search. The data from this stage was then analysed and used as input in the second stage for product design specification (PDS) to develop a motorcycle seat prototype. A total of 18 criteria of PDS were chosen for the development of the prototype. In the third stage, an experimental study was conducted among 24 traffic police riders (12 participants each in the control and experimental groups) using an existing motorcycle seat and a developed motorcycle seat prototype. Each participant was required to wear a TruPosture smart shirt (to monitor spinal angle posture) while riding a motorcycle for 20 minutes. The seating and body regions discomfort was assessed using a 100-millimetre Visual Analogue Scale (VAS) after the ride. As a result, the experimental group recorded a reduced discomfort and maintained and improved the spinal posture during the ride duration compared to the control group. From the analysis, there was a statistically significant difference (seat length, vibration, physical design, tendency to slide, the pressure under buttocks, with/without lumbar support, and with/without massager system) between the pre-test and post-test in the experimental group ($p<0.05$). Seven body regions showed a statistically significant difference in the pre-test and post-test in the experimental group,

namely the neck, shoulders, hand, upper back, lower back, buttocks, thighs and calf ($p<0.05$). There was also a statistically significant difference in all sensors at the 0th, 10th, and 20th minutes between the pre-test and post-test in the experimental group ($p<0.05$). The application of a lumbar support with a built-in massager system showed a lower angle deviation compared to the control group. Overall, the seat discomfort was reduced by 17.0% to 67% and the muscle discomfort was reduced by 15.0% to 63.0% after 20 minutes of using the prototype. As a conclusion, the motorcycle seat intervention helps reduce traffic police riders' discomfort during prolonged vehicle usage as well as support body posture, and therefore, has the potential to reduce the risk of developing MSD and spinal injury from this occupational work task.

Keywords – Seat features, visual analogue scale, body muscle, spinal angle, product design specification.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN TEMPAT DUDUK MOTOSIKAL DENGAN PEMASANGAN SISTEM URUT DALAM SOKONGAN LUMBAR BAGI MENGURANGKAN KETIDAKSELESAAN DAN MENJAGA POSTUR TULANG BELAKANG DI KALANGAN PENUNGGANG MOTOSIKAL POLIS TRAFIK

Oleh

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Penunggang motosikal polis trafik terdedah kepada postur statik yang berpanjangan menyebabkan deviasi yang ketara pada sudut otot rangka termasuk sudut lumbar (L1-L5). Perubahan postur ini adalah faktor penyumbang kepada ketidakselesaan otot, terutamanya kawasan belakang bawah kerana ia adalah salah satu penyakit moden yang serius pada masa kini. Ketidakselesaan akibat menunggang motosikal adalah isu yang perlu ditangani kerana ia mempunyai kesan gangguan jangka panjang pada otot rangka penunggang motosikal, terutamanya di kalangan kumpulan pekerjaan. Oleh itu, kajian ini bertujuan untuk menilai pemasangan sistem urut dalam sokongan lumbar untuk mengurangkan rasa tidak selesa di kalangan penunggang motosikal polis trafik. Tahap pertama penyelidikan ini mengkaji masalah ergonomik yang dialami oleh penunggang motosikal menggunakan tinjauan ketidakselesaan tempat duduk motosikal, ketidakselesaan carta badan, pencarian kajian lepas yang luas dan pencarian paten sebelumnya. Data dari tahap ini kemudiannya dianalisa dan digunakan sebagai input di peringkat kedua untuk spesifikasi reka bentuk produk (PDS) bagi menghasilkan prototaip tempat duduk motosikal. Sebanyak 18 kriteria PDS telah dipilih untuk menghasikan prototaip. Pada tahap ketiga, kajian eksperimental dilakukan di antara 24 penunggang polis trafik (masing-masing 12 peserta dalam kumpulan kawalan dan eksperimen) dengan menggunakan tempat duduk motosikal yang sedia ada dan prototaip tempat duduk motosikal yang dihasilkan. Setiap peserta dikehendaki memakai baju pintar TruPosture (untuk memantau sudut postur tulang belakang) semasa menunggang motosikal selama 20 minit. Ketidakselesaan pada tempat duduk dan bahagian badan dinilai setelah menunggang motosikal dengan menggunakan Skala Analog Visual (SAV) 100 milimeter. Hasilnya, penurunan ketidakselsesaan telah dicatat dalam kumpulan eksperimen serta dapat mengekalkan dan memperbaiki postur tulang belakang sepanjang tempoh menunggang motosikal berbanding dengan

kumpulan kawalan. Dari analisa, terdapat perbezaan yang signifikan secara statistik (panjang tempat duduk, gegaran, reka bentuk fizikal, kecenderungan untuk meluncur, tekanan di bawah punggung, dengan/tanpa sokongan lumbar, dan dengan/tanpa sistem urut) antara pra-ujian dan pasca-ujian didalam kumpulan eksperimen ($p < 0.05$). Tujuh kawasan badan menunjukkan perbezaan yang signifikan secara statistik dalam sesi pra-ujian dan pasca-ujian dalam kumpulan eksperimen, iaitu leher, bahu, tangan, belakang atas, belakang bawah, punggung, paha dan betis ($p<0.05$). Terdapat juga perbezaan yang signifikan secara statistik dalam semua sensor pada minit ke-0, ke-10 dan ke-20 antara pra-ujian dan pasca-ujian dalam kumpulan eksperimen ($p < 0.05$). Penggunaan pemasangan sistem urut dalam sokongan lumbar menunjukkan sudut deviasi yang lebih rendah berbanding kumpulan kawalan. Secara keseluruhan, ketidakselesaan tempat duduk menurun sebanyak 17.0% sehingga 67%, dan ketidakselesaan otot badan menurun sebanyak 15.0% sehingga 63.0% setelah 20 minit menggunakan prototaip. Secara kesimpulan, intervensi pada tempat duduk motosikal membantu mengurangkan ketidakselesaan penunggang motosikal polis trafik semasa penggunaan yang berpanjangan dan ia membantu menyokong postur badan, oleh itu, ia berpotensi untuk mengurangkan risiko terkena masalah otot rangka dan kecederaan tulang belakang daripada tugas pekerjaan ini.

Kata kunci – Ciri-ciri tempat duduk, skala analog visual, otot badan, sudut tulang belakang, spesifikasi reka bentuk produk

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I certify that a Thesis Examination Committee has met on 24 June 2021 to conduct the final examination of Nur Athirah Diyana binti Mohammad Yusof on her thesis entitled “Evaluation of Motorcycle Seat with Lumbar Support Massager in Reducing Discomfort and Maintaining Spinal Posture among Traffic Police Riders” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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LIST OF ABBREVIATIONS

MSD	Musculoskeletal Disorders
LBP	Lower Back Pain
PDRM	Polis Diraja Malaysia
RMP	Royal Malaysian Police
SOCSO	Social Security Organisation
SOP	Standard Operating Procedure
VAS	Visual Analogue Scale
PDS	Product Design Specification

CHAPTER 1

INTRODUCTION

1.1 Research Background

The term “motorcycle” has been defined and described extensively by various sources. Cossalter (2006) defined motorcycle as a spatial mechanism consisting of four rigid bodies comprised of the front wheel, rear wheel, rear assembly, which included the seat, frame, tank, and motor-transmission drivetrain group; and the front assembly consisting of the fork, handlebars, and steering head in a book entitled Motorcycle Dynamics. Meanwhile, the National Highway Traffic Safety Administration (NHTSA) defined a motorcycle as a vehicle with motive power having a seat for the rider’s use for travel that does not have more than two wheels (Glenn, 2011). However, a previous study defined a motorcycle as any given single-tracked, automated, semi-manual or manual transmission mass production, prototype, or two-wheeled motor vehicles concept, powered by just a rare wheel driven by the chain, shaft by two or four strokes internal combustion engine. It comes with various design, types, and purposes such as comfort and speed (Ma’arof et al., 2012).

Motorcycles are a common type of transportation mode in Malaysia. An estimated 11 million motorcycles are used in Malaysia, followed by 10 million cars, 62 thousand buses, 99 thousand taxies, and 862 thousand other vehicles, leading to the number of vehicles available in Malaysia to be about 26 million in 2015 (Road and Transport Department, 2016). It is undeniable that motorcycle costs are relatively lower than cars; however, motorcycles are the most hazardous vehicle mode and, therefore, require more effort to improve their safety and comfort level. Although motorcycles are usually used for short-distance travel as they are the most convenient, cheap, and practical, they are also used as the main transportation mode for some occupations such as courier, food delivery, postal delivery, and traffic police officers.

The majority of traffic police use a motorcycle as the main mode of transportation to complete the work task, such as escorts and patrols (Diyana et al., 2019). Most of them need to use a high-powered motorcycle to move from one place to another because it is fast and convenient for long-distance transport. However, Rashid et al. (2021) mentioned that riding a motorcycle with a controlling motorcycle along with a demanding workload in duties environment would lead to a high risk of accidents due to muscle fatigue and discomfort. Back problems are the most reported by occupational riders and drivers than any other occupational groups due to prolonged riding or driving, leading to passive stiffness changes in the lumbar spine, accelerated disc generation, and associated muscle discomfort (De Carvalho & Callaghan, 2011; Battie et al., 2002). Arunachalam et al. (2018) stated that motorcycle accidents happen because of a multi-factorial phenomenon, but uncomfortable riding posture is

one of the significant factors for rider's muscular fatigue, which can lead to accidents (Balasubramanian & Jagannath, 2014; Velagapudi et al., 2010; Dutta et al., 2014). Previous studies have found that the discomfort ratings of body regions among motorcycle riders were very high in Malaysia, especially at the lower back area and at shoulder and arms after riding a motorcycle (Karmegam et al., 2008; Shafiei et al., 2015; Diyana et al., 2019). Chen et al. (2009) believed that a continuous riding of a standard motorcycle for an extended period of time would result in a high level of muscle fatigue and health problems. Shafiei et al. (2015) found that ergonomic motorcycle seat design helps to reduce muscle discomfort and musculoskeletal disorders (MSD) among motorcycle riders. However, the current feature in current motorcycle seat still lacks in provide a good posture for the occupational rides who usually use motorcycles for up to 12 hours a day.

Hence, it is vital to look at motorcycles from the human factors and ergonomics (HFE) perspective. Ergonomics is multidisciplinary with a safe, open, and comfortable workplace for employees and their workplace (PA, 2020). In the context of motorcycles, ergonomics is intended to improve the interaction between user (motorcycle rider) and machine (motorcycle support features), which is adaptable with the environment. According to Aragaki et al. (2021), ergonomics aims to minimise discomforts that cause poor work performance due to long-term impairment. Donnelly et al. (2009) asserted that the inability to fully accommodate the position of the seat ergonomically by police officers during a shift can increase the discomfort level over time, ultimately leading to MSD.

Compared to cars, motorcycle seat intervention had minimal studies, especially when it comes to a massager system. There are only several studies that focused on the motorcycle seat design intervention (Karuppiah et al., 2012; Patil et al., 2014; Eida et al., 2020). Hence, the automotive industry strongly encourages the research field to focus more on comfort assessment, especially on the seat design and body discomfort (Kolich, 2008). Parallel with the rapid growth of the motorcycling industry, interventions on motorcycle seats are becoming an increasingly important area for research, especially for occupational groups that require prolonged riding, such as traffic police riders. However, there is still a minimal product that focuses on occupational riders groups, especially when it comes to lumbar support with built-in massager system among motorcycle riders to reduce and eliminate discomfort. Thus, it has become paramount to conduct and develop an intervention of motorcycle seat design for high-powered traffic police motorcycles as a start towards an ergonomic lifestyle in an occupation that provides comfort and a healthy working environment.

1.2 Problem Statement

World Health Organization (WHO) has recognised MSD as a significant health problem that directly affects user behaviour and as an influential factor that causes accidents (Hilton & Whiteford, 2010; Sobeih et al., 2009). In Malaysia,

work-related MSD are alarming and are continuously increasing every year as statistics showed 708 MSD cases reported in 2016, 1006 cases in 2017, and 1354 cases in 2018 (SOCSO, 2018). According to Makhsous et al. (2003), MSD especially lower back pain (LBP) can cause a tremendous effect on economic and productivity which is also a primary problem in the US industry.

Riding discomfort while riding a motorcycle has been widely discussed recently by previous research studies, implying that this issue has become a critical concern in the research field. Based on Karrupiah et al. (2011), riding discomfort is a terminology that related with the motorcyclists which the discomfort symptoms appeared on the body parts due to the sitting posture during riding process. In this study, riding discomfort is defined as a discomfort experienced after 20 minutes riding session which is classified into two categories: muscle discomfort and motorcycle seat discomfort. Muscle discomfort among motorcycle riders showed the worst trend when most of the research found that prolonged rides for more than 20 minutes would contribute to the muscle discomfort, especially at the lower back, shoulder, and neck (Karuppiah et al., 2012; Khamis et al., 2014; Balasubramaniam & Jagganath, 2014). Meanwhile, for motorcycle seat discomfort, to the best of the author's knowledge, there is no data and research conducted yet regarding this problem, unlike car seat discomfort, which is well-discussed by the previous studies and always had room for improvement and invention (Looze et al., 2003; Mansfield et al., 2007; Deros et al., 2009; Sammonds et al., 2014) . Besides, the occupational use of the motorcycle also is limited in the research field, which could impose health risks and early retirement from the occupations (Muzammil et al., 2019).

In Malaysia, the trend of early retirements among police officers is at an alarming level due to the workload, pressure, and even health problems (BH, 2018). Previous studies found that approximately 50% of the traffic police officers use motorcycles as their main vehicle while on duty (Diyana et al., 2019; Yusof et al., 2016). The traffic police force in Malaysia is under the Department of Investigation and Traffic Enforcement which is one of the main components of the Malaysian Royal Police (MRP). Traffic police riders represent one of the most critical subcomponents in this department. They are responsible to escort, patrol selected locations, and fine any offence of road users in their eight to 12-hours working shift. Most of the motorcycles used are high-powered motorcycles (such as Honda ST 1300 with 1500 cc engine V6, Honda VFR 800 with 787 cc engine, and Honda CBX 750 with 747 cc engine) compared to ordinary motorcycles of which the average engine power is only 110 cc (Yusof, 2016).

However, this study focused on Honda CBX 750P21 (747cc) motorcycle because a majority of traffic police riders in Malaysia use this motorcycle compared to other motorcycles. Moreover, this type of motorcycle is only used by the police departments in several countries. From a previous research study on the CBX 750P21 motorcycle, it was found that 88.3% of traffic police riders suffered from MSD with 34.3% of them suffering from lower back pain due to static posture and prolonged sitting while riding the motorcycle (Diyana et al., 2019). Another previous study also revealed that more than half (54.7%) of the

traffic police riders rode high-powered motorcycles for an average of 5.64 hours per day with a fixed posture leading to increased discomfort from prolonged sitting that enhanced muscle fatigue (Yusof, 2016). This showed that most of their working time involves riding motorcycles.

Mirbod et al. (1997) studied in Japan and Gyi and Porter (1998) in Canada stated that roughly half of the police officers were exposed to prolonged riding and driving for more than five hours per day and more than 25000 km per annum which had been categorised as over-exposure of body muscles to fatigue. In Malaysia, static postures and prolonged riding led to muscle discomfort and exposed the officers to the risk of MSD after a few hours of riding session (Diyana et al., 2019). Therefore, mobile police officers have a greater prevalence of absenteeism due to MSD than other officers in different departments (McKinnon, Callaghan, & Dickerson, 2012). Gyi and Porter (1998) concluded that traffic police officers had a high prevalence of muscle discomfort in the lower back since they had high exposure to driving which they need to spend their shift in the same car all day. They agreed that traffic police officers experiencing MSD for longer periods within the past year compare to other general duty police officers. The main cause of this problem arises because traffic police officers are exposed to prolonged riding and driving, static posture, awkward posture, and limited adjustability of workstation, leading to muscle discomfort and strain. A previous study in Canada highlighted that the majority of the policemen did not experience low back pain before recruiting the force which proves that some factors of policing caused the muscle discomfort among policemen (Anderson et al., 2011). The summarised of MSD in previous studies among police officers was illustrated in Table 1.1.

Table 1.1: The summarised of MSD among police officers

Previous study of MSD among police officers				
Author (year)	**Country**	**Number of respondents**	**Part of studied**	**Prevalence of MSD**
Diyana et al. (2019)	Malaysia	137 traffic police riders	Neck, shoulder, back, elbow, forearm, low back, wrist, hips,knee, ankle	67.9%
Ana et al., (2015)	Brazil	262 police officers	Neck, shoulder, back, elbow, forearm, low back, wrist, hips,knee, ankle	75%
Phadke et al., (2015)	India	270 traffic police officers	Neck, shoulder, back, elbow, forearm, low back, wrist, hips,knee, ankle	74%

Cho et al., (2014)	Korea	353 police officers	Neck, shoulder, elbow, lower back, wrist, leg	76.8%
Nazmul (2013)	Bangladesh	40 traffic police officers	Lower back	80%
Anderson et al., (2011)	Canada	30 police officers	Lower back	86%
Brown et al., (1998)	Canada	1002 police officers	Lower back	62%
Gyi and Porter (1998)	United Kingdom	80 traffic police officers and 91 general duty officers	Lower back	38% (traffic police officers) and 22% (general duty officers)
Mirbod et al., (1997)	Japan	119 traffic police riders	Hand-arm and shoulder	45.4%

According to Makhsous et al. (2003), sitting decreases lumbar lordosis compared to the standing posture, resulting in increased disc pressure and low back muscle activity. This is because while sitting, the ischial tuberosity mainly supports the majority of the upper body weight. Increased pressure in this area is significantly associated with increased spinal load (Pope, Goh, & Magnusson, 2002). Van Nieuwenhuyse et al. (2004) stated that occupations that involve prolonged sitting have a 3.2 times greater risk of experiencing muscle discomfort and developing MSD within the first employment year compared to those who did not involve prolonged sitting. Riding a motorcycle exposes the officers to excessive physical demand, especially for prolonged periods. They would tend to feel discomfort and possibly fatigue while sitting in the same position with restricted movements. Discomfort and fatigue usually occur when muscles become stiff, and the blood flow is reduced during prolonged riding (Council of North-South Motorcycle Wales, 2005). In addition, they cannot maintain an ideal posture for a long period due to limited human capabilities. This is because when the person in sitting position, body weight is transferred to the armrest, backrest, floor or any supporting areas. Pope et al. (2002) point out that sitting without lumbar support could led to 35% intradiscal pressure higher than standing and usually ideal sitting posture without lumbar support cannot maintain for long period of time due to human capabilities.

Previous research found that lumbar lordosis decreased by approximately 43º while sitting on an automotive seat compared to standing (De Carvalho & Callaghan, 2015). The reduction in lumbar lordosis during sitting has been associated with increased tension on the posterior spinal column and intradiscal pressure, which could lead to slipped disc (De Carvalho et al., 2010). Besides that, the upright sitting posture without lumbar support leads to an unnatural

spinal curve. Seated postures have been viewed as potentially harmful and considered as one of the major contributing factors for MSD such as discomfort in the lower back, neck, and shoulder. In order to reduce this problem, the ergonomic intervention has to play an important role in providing sitting comfort due to increased exposures to seated postures (Kyung, Nussbaum, & Babski-Reeves, 2008).

Epidemiological studies and literature review stated that many risk factors can influence the discomfort rating, especially during riding or driving, such as occupational factors (Diyana et al., 2019), seat characteristics (Donnelly et al., 2009; Gyi & Porter, 1998; Speed, Harris, & Keegel, 2018) and body postures (Gruevski et al., 2016; Karuppiah, Salit, Ismail, Ismail, & Tamrin, 2012). The occupational factors include years of service (Ghasemkhani, Mahmudi, & Jabbari, 2008) and long riding duration (Balasubramanian, Jagannath, & Adalarasu, 2014). Meanwhile, seat characteristics include the presence of lumbar support (Karuppiah et al., 2012), and a massager (Durkin et al., 2006). However, to the best author's knowledge, there is still a lack of studies on a high-powered motorcycle rider compared to car drivers, particularly in seat intervention. Thus, in this regard, a motorcycle seat prototype is developed and assessed in this study to determine the effectiveness in the context of ergonomics among traffic police riders.

1.3 Study Justification

In Malaysia, traffic police riders are qualified and well-trained to ride a high-powered motorcycle. Their work task requires them to be physically fit and medically healthy at all times. Any discomfort experienced while riding a motorcycle during duty might decrease their performance, strength, and capability. However, there are scanted reference data, profiles, and even baselines in relation to the statistics among traffic police on occupational health. This limited availability of data makes it difficult to develop evidence-based prevention programs for the officers as well as the SOP for a healthy working environment. There is also no such specific guideline related to occupational safety and health for law enforcement workers in Malaysia compared to developed countries such as the United States of America. Thus, this study can be one of the baseline data in occupational health among traffic police in Malaysia which would be beneficial to researchers, policymakers, employers, and employees.

Muscle discomfort and MSD are affecting people worldwide with high recurrence rates and have caused the loss of function and disability. These disorders usually affect vehicle users, especially motorcycle riders as they are exposed to prolonged riding in awkward postures due to the limited lumbar support design for this group of users. In order to fill the gap of this problem, an engineering and ergonomic intervention is needed for motorcycle riders to increase their comfort level, reduce lower back pain, and improve their work environments, especially for those exposed to prolonged riding. Seats are one of the most important

components of vehicles, and they are the place on which drivers and riders spend most of their time travelling. For example, according to a previous study by Yusof (2016), a traffic police rider sits for approximately 28.2 hours per week while riding, which accumulates to 1466 hours of riding time per year, resulting in muscle discomfort and MSD, especially at the lower back area. Thus, it is recommended to tackle this problem to reduce the number of cases among traffic police officers.

Besides that, the automotive industry strongly encourages researchers to focus more on comfort assessment, specifically dedicated to the seat and target postures in the occupational (on-the-road) setting. In the last two decades, public awareness and communities' attitude toward comfort and safety have begun to change, in which comfortable sitting is no longer considered a luxury, but a requirement, especially in the occupational area. Many previous research works on seating comfort of motorcycles have emphasised the need for further research in this area (Balasubramanian et al., 2014; Karuppiah et al., 2012; Patil, Bajpai, Verma, & Technology, 2014; Rajhans & S. Amrutkar, 2011). However, these works are limited in terms of occupational and on-the-road settings. Most of the research were focused on laboratory and clinical settings, especially for motorcycle discomfort and seat design. Furthermore, most of the massager systems are present in car seat features instead of motorcycle seat. Thus, it is important for this research to be conducted to develop an intervention for high-powered motorcycle seat design as well as to provide an ergonomic and comfortable working environment for traffic police riders.

1.4 Research Objectives

1.4.1 General Objective

To evaluate the effectiveness of lumbar support with a built-in massager system on a high-powered motorcycle seat in order to reduce discomfort among traffic police riders.

1.4.2 Specific Objectives

The specific objectives of this study are as follows:

1.4.2.1 To develop a seat discomfort survey for a high-powered motorcycle.

1.4.2.1 To identify the ratings of motorcycle seat discomfort among traffic police riders.

1.4.2.2 To identify the ratings of muscle discomfort among traffic police riders.

1.4.2.3 To develop lumbar support for motorcycle seat with a built-in massager system for a high-powered traffic police motorcycle.

1.4.2.4 To compare the motorcycle seat discomfort ratings between the pre-test and post-test sessions in two groups (control and experimental groups).

1.4.2.5 To compare the muscle discomfort ratings between the pre-test and post-test sessions in two groups (control and experimental groups).

1.4.2.6 To compare the spinal angle profiles between the pre-test and post-test sessions in two groups (control and experimental groups).

1.5 Research Hypotheses

1.5.1 There is a significant difference of motorcycle seat discomfort ratings between the pre-test and post-test sessions in the two groups.

1.5.2 There is a significant difference of muscle discomfort ratings between the pre-test and post-test sessions in the two groups.

1.5.3 There is a significant difference of spinal angle profiles between the pre-test and post-test sessions in the two groups.

1.6 Scope of Study

Musculoskeletal disorders (MSD) usually affects vehicle users, especially motorcyclists, as the current feature of a motorcycle seat still lacks in providing good posture support for the riders. Therefore, this study primarily focused on the effectiveness of the development of lumbar support with a built-in massager system in terms of reducing muscle discomfort, motorcycle seat discomfort and mintaining spinal posture of traffic police riders. This prototype was developed based on Pugh's total design process model. The competent police trainer (high-powered motorcycle) in Maktab Teknik PDRM Bakri, Muar,were actively engaged throughout the prototype development phase with an opinion and suggestion from the research team and expertise. The prototype then was tested among traffic police riders under Escort Unit in Kuala Lumpur Traffic Police Station. Overall, this study takes almost two years in prototype development and testing, recruitment of officers as well as data collection.

1.7 Thesis Contribution

The contribution of this thesis involved four categories: methodology, industry, knowledge, and practical. For methodology, this thesis had successfully developed a new discomfort questionnaire for a high-powered motorcycle seat which known as Motorcycle Seat Discomfort Survey (MSDS). This survey has

possibility to become a tool in the future research. In term of industry, this thesis had successfully developed a new invention for a high-powered motorcycle seat which meet the Malaysian physical dimension. Besides, this research had successfully developed an industry partner with PDRM in Bukit Aman Headquarters and Maktab Teknik PDRM Bakri Muar which the end-user is focused in this research. This thesis proved the effectiveness of this motorcycle seat prototype (lumbar support with built-in massager system) and successfully published five papers for the knowledge contribution. Last but not least, in terms of practicality, this research had fulfilled the user needs.

The present invention offers a novel apparatus that provides firm lumbar support for the rider without reducing the size of rider space and, at the same time, provides a massager system to relieve discomfort for traffic police riders. The present invention integrates adjustable lumbar support with a seat massager. The rider can continuously use the massager (4 minutes off to 1 minute on) or switch it on when needed. The lumbar support on the motorcycle seat can support different heights of riders as the lumbar support height can be adjusted, thereby giving the riders greater comfortability. This study is the first study that has proposed a prototype (lumbar support with built-in massager) for occupational using a high-powered motorcycle. This prototype was also evaluated using an occupational (on-the-road) setting in which riding in an actual working condition was applied.

1.8 Linkages of Research Chapters

This section describes the relationship between each chapter presented in this thesis. This thesis consists of eight chapters. Each chapter is segmented to achieve each specific objective outlined in this study. Except for Chapters One, Two and Eight, the rest of the other chapters are presented in a structure akin to a research paper containing a standalone introduction, methodology, results, and conclusion.

The first chapter is an introductory section describing the research area and outlines the background and rationale of this study. The second chapter reports the information established in the literature related to ergonomic motorcycle seat design, riding posture, and health effects (MSD and muscle discomfort). This chapter elaborates extensively on the conceptual model and framework significant to this study. The methodologies and approach adopted in this study are also described in detail with regards to previous studies. This chapter includes the development of the conceptual framework based on the selected model in the previous study. The finalised framework was used as a guide to the entire process integrated into this research study.

The third chapter discusses the discomfort ratings of motorcycle seat discomfort using Motorcycle Seat Discomfort Survey (MSDS). The survey, which consisted of 14 items, was used in a field data collection involving 71 traffic police riders at

the Kuala Lumpur Traffic Police Station. The fourth chapter analyses and reports the discomfort ratings of body regions among 137 traffic police riders. Chapters Three and Four provide an overview of the ergonomic issues on discomfort faced by traffic police riders in Malaysia, linked with Chapter Five in order to identify the PDS and to develop a prototype.

The fifth chapter described the procedure and process of prototype development (lumbar support with a built-in massager system) in details. The development of a prototype in this chapter involved three stages: problem identification, development of the prototype, and initial testing.

Chapters Six and Seven describe the effectiveness of the prototype used by traffic police riders. This is a part of significant research in this study, and the output is divided into two Chapters. Chapter Six discusses muscle discomfort ratings and motorcycle seat discomfort ratings for the control and experimental groups. Meanwhile, Chapter Seven reports the spinal angle profiles of traffic police riders to determine the effectiveness of motorcycle seat prototypes in maintaining body posture in the control and experimental groups.

REFERENCES

Alyami, H., & Albarrati, A. M. (2016). Comparison of Spinal Angles in a Typing Task on a Laptop and a Desktop Computer: A Preliminary Study. *American Journal of Occupational Therapy*, *70*(6), 7006350020p1-7006350020p8.

Amitrano, R., & Tortora, G. (2012). *Update: anatomy & physiology laboratory manual*. Cengage Learning.

Amrutkar, A. S., & Rajhans, N. R. (2011). Ergonomic posture for motorcycle riding. In *Conference Paper*.

Anderson, G. S., Amber, Z., & Darryl, B. P. (2011). Police Officer Back Health. *The Journal of Criminal Justice Research (JCJR*), 2(1), 1-17.

Andrew, W. (2010). Innova Pain Clinic: Motorcycle riding posture. Retrieved from http://www.innova-pain.com/2012/03/02/motorcycle-riding-posture/

Aragaki, D., Saby, A., Zappaterra, M., & Escorpizo, R. (2021). Occupational Medicine and Vocational Rehabilitation. In *Braddom's Physical Medicine and Rehabilitation* (pp. 89-99). Elsevier.

Aroeira, R. M. C., Furlan, R. M. M. M., Pertence, A. E. D. M., Casas, E. B. D. L., & Greco, M. (2017). Relationship between head posture and lumbar curve in a sitting position: a biomechanical study. *Fisioterapia em Movimento*, *30*(3), 453-461.

Arunachalam, M., & Karmakar, S. (2018, August). Ergonomic Design and Evaluation of Innovative MainStand of Motorcycle. In *Congress of the International Ergonomics Association* (pp. 1099-1111). Springer, Cham.

Badrulhisyam, A. J., Nurhayati, M. N., AJ, R. I., & AA, N. S. (2020). PRELIMINARY STUDY ON THE ERGONOMIC DESIGN OF MOTORCYCLE SEAT FOR COMFORT USAGE. *Malaysian Journal of Public Health Medicine*, *20*(Special1), 231-237.

Balasubramanian, V., & Jagannath, M. (2014). Detecting motorcycle rider local physical fatigue and discomfort using surface electromyography and seat interface pressure. *Transportation research part F: traffic psychology and behaviour*, *22*, 150-158.

Balasubramanian, V., Jagannath, M., & Adalarasu, K. (2014). Muscle fatigue based evaluation of bicycle design. *Applied ergonomics*, *45*(2), 339-345.

Battié, M. C., Videman, T., Gibbons, L. E., Manninen, H., Gill, K., Pope, M., & Kaprio, J. (2002). Occupational driving and lumbar disc degeneration: a casecontrol study. *The lancet*, *360*(9343), 1369-1374.

Bener, A., Verjee, M., Dafeeah, E. E., Falah, O., Al-Juhaishi, T., Schlogl, J., ... & Khan, S. (2013). Psychological factors: anxiety, depression, and somatization symptoms in low back pain patients. *Journal of pain research*, *6*, 95.

Bernard, B. P., & Putz-Anderson, V. (1997). Musculoskeletal disorders and workplace factors; a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. *National Institute of Occupational Safety and Health*, Cincinnati, OH.

BH. (2018). *Trend polis bersara awal di tahap membimbangkan* – Fuzi. Retrived from https://www.bharian.com.my/berita/nasional/2018/11/499059/trend-polis-bersara-awal-di-tahap-membimbangkan-fuzi

Bhise, V. D. (2011). *Ergonomics in the automotive design process*. CRC Press.

Boussenna, M., Corlett, E. N., & Pheasant, S. T. (1982). The relation between discomfort and postural loading at the joints. *Ergonomics*, *25*(4), 315-322.

Bovenzi, M. (2010). A longitudinal study of low back pain and daily vibration exposure in professional drivers. *Industrial health*, *48*(5), 584-595.

Burgel, B. J., & Elshatarat, R. A. (2017). Psychosocial work factors and low back pain in taxi drivers. *American journal of industrial medicine*, *60*(8), 734-746.

Cambridge Dictionary (2020). Retrieved from https://dictionary.cambridge.org/dictionary/english/discomfort

Carcone, S. M., & Keir, P. J. (2007). Effects of backrest design on biomechanics and comfort during seated work. *Applied Ergonomics*, *38*(6), 755–764.

Cardoso, M., Girouard, M., Callaghan, J. P., & Albert, W. J. (2016). An ergonomic evaluation of city police officers: an analysis of perceived discomfort within patrol duties. *International Journal of Occupational Safety and Ergonomics,* 23(2), 175–184. doi:10.1080/10803548.2016.1249728

Chen, H.C., W.C. Chen, Y.P. Liu, C.H. Chen & Y.T. Pan. (2009). Whole-body vibration exposure experienced by motorcycle riders – An evaluation according to ISO 2631-1 and ISO 2631-5 standards. International Journal of Industrial Ergonomics, 39: 708–718.

Chen, J. C., Chang, W. R., Chang, W., & Christiani, D. (2005). Occupational factors associated with low back pain in urban taxi drivers. *Occupational medicine*, *55*(7), 535-540.

Chunco, R. (2011). The effects of massage on pain, stiffness, and fatigue levels associated with ankylosing spondylitis: a case study. *International journal of therapeutic massage & bodywork*, *4*(1), 12.

Corlett, E. N., & Bishop, R. P. (1976). A technique for assessing postural discomfort. Ergonomics, 19(2), 175-182.

Corlett, E.N., Wilson, J., Manenica, I. (Eds.), 1986. The Ergo-nomics of Working Postures. Section 5: Seats and Sitting.Taylor and Francis, London

Cossalter, V. (2006). *Motorcycle dynamics*. Lulu. com. Retrieved from https://books.google.com.my/books/about/Motorcycle_Dynamics.html?id=rJTQxITnkbgC&redir_esc=y

Daruis, D. D. I., Deros, B. M., & Nor, M. J. M. (2011). Malaysian sitting anthropometry for seat fit parameters. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *21*(5), 443–455. https://doi.org/10.1002/hfm.20237

De Carvalho, D. E., & Callaghan, J. P. (2011). Passive stiffness changes in the lumbar spine and effect of gender during prolonged simulated driving. *International Journal of Industrial Ergonomics*, *41*(6), 617-624.

De Carvalho, D. E., Soave, D., Ross, K., & Callaghan, J. P. (2010). Lumbar spine and pelvic posture between standing and sitting: a radiologic investigation including reliability and repeatability of the lumbar lordosis measure. *Journal of manipulative and physiological therapeutics*, *33*(1), 48-55.

De Looze, M. P., Kuijt-Evers, L. F., & Van Dieen, J. A. A. P. (2003). Sitting comfort and discomfort and the relationships with objective measures. *Ergonomics*, *46*(10), 985-997.

Deros, B. M., Daruis, D., & Mohd Nor, M. J. (2009). Evaluation of Car Seat Using Reliable and Valid Vehicle Seat Discomfort Survey. *Industrial Engineering and Management Systems (IEMS)*, *8*(2), 121–130.

DeShaw, J., & Rahmatalla, S. (2016). Effect of lumbar support on human-head movement and discomfort in whole-body vibration. *Occupational Ergonomics*, *13*(1), 3-14.

Diyana, N. A., Karuppiah, K., Rasdi, I., Sambasivam, S., Tamrin, S. B. M., Mani, K. K., Putri, A.S. & Azmi, I. (2017). Vibration exposure and work-musculoskeletal disorders among traffic police riders in Malaysia: A review. *Annals of Tropical Medicine and Public Health*, 10(2), 334.

Donnelly, C. J., Callaghan, J. P., and Durkin, J. L. (2009). The effect of an active lumbar system on the seating comfort of officers in police fleet vehicles. *International Journal of Occupational Safety and Ergonomics, 15*(3):297-307.

Durkin, J. L., Harvey, A., Hughson, R. L., & Callaghan, J. P. (2006). The effects of lumbar massage on muscle fatigue, muscle oxygenation, low back discomfort, and driver performance during prolonged driving. *Ergonomics*, *49*(1), 28-44.

Dutta, K., Basu, B., & Sen, D. (2014). Identification and quantification of stressors affecting motorized two-wheeler riders: an ergonomic attempt. *Int J Res*, *2*(1), 13-25.

Eida Nadirah R, Badrulhisyam AJ, Nurhayati MN, Rifqi Irzuan AJ, Mohamad Asmidzam A, & Nor Syazwani AA. (2020). PRELIMINARY STUDY ON THE ERGONOMIC DESIGN OF MOTORCYCLE SEAT FOR COMFORT USAGE. *Malaysian Journal of Public Health Medicine*, *20*(Special1), 231-237. https://doi.org/10.37268/mjphm/vol.20/no.Special1/art.700

Estrada, J. E., & Vea, L. A. (2016, May). Real-time human sitting posture detection using mobile devices. In *2016 IEEE Region 10 Symposium (TENSYMP)* (pp. 140-144). IEEE.

Franz, M., Zenk, R., Vink, P., & Hallbeck, S. (2011). The effect of a lightweight massage system in a car seat on comfort and electromyogram. *Journal of manipulative and physiological therapeutics*, *34*(2), 107-113.

Frost, B. A., Camarero-Espinosa, S., & Foster, E. J. (2019). Materials for the spine: anatomy, problems, and solutions. *Materials*, *12*(2), 253.

Furlan, A. D., Giraldo, M., Baskwill, A., Irvin, E., & Imamura, M. (2015). Massage for low-back pain. *Cochrane database of systematic reviews*, (9).

Girouard, M. M., Rae, M. M., Croll, J., Callaghan, J. P., McKinnon, C. D., & Albert, W. J. (2013, September). Police officer discomfort and activity characterization during a day shift and a night shift. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 57, No. 1, pp. 1820-1824). Sage CA: Los Angeles, CA: SAGE Publications.

Glenn W. (2011). What is motorcycle? Retrieved March 11, 2012, from webBikeWorld.com website: http://www.webbikeworld.com/motorcycles/definition-of-a-motorcycle.htm

Goonatilake, S. (2014). Ancient Sri Lankan Lumbar-Supported Seats. *Ergonomics in Design*, *22*(1), 27-30.

Grondin, D. E., Triano, J. J., Tran, S., & Soave, D. (2013). The effect of a lumbar support pillow on lumbar posture and comfort during a prolonged seated task. *Chiropractic & manual therapies*, *21*(1), 1-9.

Gruevski, K. M., Holmes, M. W., Gooyers, C. E., Dickerson, C. R., & Callaghan, J. P. (2016). Lumbar postures, seat interface pressures and discomfort responses to a novel thoracic support for police officers during prolonged simulated driving exposures. *Applied ergonomics*, *52*, 160-168.

Grujicic, M., Pandurangan, B., Xie, X., Gramopadhye, A. K., Wagner, D., & Ozen, M. (2010). Musculoskeletal computational analysis of the influence of

car-seat design/adjustments on long-distance driving fatigue. *International Journal of Industrial Ergonomics*, *40*(3), 345-355.

Guo, L. X., Dong, R. C., & Zhang, M. (2016). Effect of lumbar support on seating comfort predicted by a whole human body-seat model. *International Journal of Industrial Ergonomics*, *53*, 319-327.

Gyi, D. E., & Porter, J. M. (1998). Musculoskeletal problems and driving in police officers. *Occupational medicine*, *48*(3), 153-160.

Hafidzul, H. M. N. (2016). Polis wujud Jabatan Trafik Mac ini. *myMetro.* Retrieved from http://www.hmetro.com.my/node/104175

Hafzi, M. M., Rohayu, S., Faradila, P. N., & Wong, S. V. (2011). Prevalence and risk factors of musculoskeletal disorders of motorcyclists. *Prevalence*, 1.

Haristiani, R., & Marten, R. (2020). Correlation Between Work Duration and Driver Sitting Position With Low Back Pain of the Drivers at Malengkeri Station Makassar. *Journal of Islamic Nursing*, *5*(2), 114-120.

Harkness, E. F., MacFarlane, G. J., Silman, A. J., & McBeth, J. (2005). Is musculoskeletal pain more common now than 40 years ago?: Two population-based cross-sectional studies. *Rheumatology*, *44*(7), 890-895.

Hartvigsen, J., Hancock, M. J., Kongsted, A., Louw, Q., Ferreira, M. L., Genevay, S., ... & Smeets, R. J. (2018). What low back pain is and why we need to pay attention. *The Lancet, 391*(10137), 2356-236

Hasson, D., & Arnetz, B. B. (2005). Validation and findings comparing VAS vs. Likert scales for psychosocial measurements. *International Electronic Journal of Health Education*, *8*, 178-192.

Hilton, M. F., & Whiteford, H. A. (2010). Interacting with the public as a risk factor for employee psychological distress. *BMC Public Health,10(*435).

Holmes, M. W. R., McKinnon, C. D., Dickerson, C. R., & Callaghan, J. P. (2013). The effects of police duty belt and seat design changes on lumbar spine posture, driver contact pressure and discomfort. *Ergonomics,* 56(1), 126-136.

Honda. (1996). *Ride Smart.* Canada: Forest Stewardship Council

Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., Blyth, F., ... & Buchbinder, R. (2012). A systematic review of the global prevalence of low back pain. *Arthritis & Rheumatism,* 64(6), 2028-2037.

Ibusuki, U., & Kaminski, P. C. (2007). Product development process with focus on value engineering and target-costing: A case study in an automotive company. *International Journal of Production Economics*, 105(2), 459-474.

Irwan Syah MY, Ruhaizin S, Ismail, M.H, & Ahmad Zuhairi AM. (2020). ACCESSING DRIVING POSTURE AMONG ELDERLY TAXI DRIVERS IN MALAYSIAN USING RULA AND QEC APPROACH. *Malaysian Journal of Public Health Medicine*, *20*(Special1), 116-123. https://doi.org/10.37268/mjphm/vol.20/no.Special1/art.671

Jacob, V. D., Ankur, S. N. Fady, Y. H., Philip, K. L., Daniel, D. B., & Kern, S. (2019). *Chapter 2: General Spine Anatomy and Long Tract Pathway.* New York, NY: Thieme.

Jagannath, M., & Balasubramanian, V. (2014). Assessment of early onset of driver fatigue using multimodal fatigue measures in a static simulator. *Applied ergonomics*, 45(4): 1140-1147.

Jahanshahi, A. A., Gashti, M. A. H., Mirdamadi, S. A., Nawaser, K., & Khaksar, S. M. S. (2011). Study the effects of customer service and product quality on customer satisfaction and loyalty. International Journal of Humanities and Social Science, 1(7), 253-260.

Jeon, K. & Fahmi, A. S. (2010). *Polis Diraja Malaysia.* Selangor, Malaysia: NR Red One Network Enterprise.

Jiao, J., Xu, Q. L., & Helander, M. G. (2007). Analytical modeling and evaluation of customer Citarasa in vehicle design, *Industrial Engineering and Engineering Management,* 1277-1281

Karmegam, K., Ismail, M. Y., Sapuan, S. M., Bahri, M. T., Shuib, S., & Seetha, P. (2009). A study on motorcyclist's riding discomfort in Malaysia. *Engineering E-Transaction*, *4*(1), 39–46. Retrieved from http://umepublication.um.edu.my/filebank/published_article/2485/828.pdf

Karmegam, K., Sapuan, S. M., Ismail, M. Y., Ismail, N., Bahri, M. S., & Seetha, P. (2013). Motorcyclist's riding discomfort in malaysia: Comparison of BMI, riding experience, riding duration and riding posture. *Human Factors and Ergonomics in Manufacturing & Service Industries,* 23(4), 267-278.

Karuppiah, K., Salit, M. S., Ismail, M. Y., Ismail, N., & Tamrin, S. (2012). Evaluation of motorcyclist's discomfort during prolonged riding process with and without lumbar support. *Anais da Academia Brasileira de Ciências*, *84*(4), 1169-1188.

Karuppiah, K., Salit, M. S., Ismail, M. Y., Ismail, N., & Tamrin, S. B. M. (2011). Conceptual design of motorcycle's lumbar support using motorcyclists' anthropometric characteristics. Maejo International Journal of Science and Technology, 5(1), 69–82.

Khamis, N. K., Md Deros, B., & Nuawi, M. Z. (2014). Understanding the effect of discomfort level towards motorcycle riders among teenagers: a

preliminary study. In *Applied Mechanics and Materials* (Vol. 663, pp. 480-484). Trans Tech Publications Ltd.

Kim, T. H., Kim, Y. T., & Yoon, Y. S. (2005). Development of a biomechanical model of the human body in a sitting posture with vibration transmissibility in the vertical direction. *International Journal of Industrial Ergonomics*, *35*(9), 817-829.

Kolich, M. (2008). A conceptual framework proposed to formalize the scientific investigation of automobile seat comfort. *Applied ergonomics*,*39*:15-27.

Kolich, M., & White, P. L. (2004). Reliability and validity of a long term survey for automobile seat comfort. *International Journal of Vehicle Design*, *34*(2), 158–167. https://doi.org/10.1504/IJVD.2004.003899

Kolich, M., Taboun, S. M., & Mohamed, A. I. (2000). Low back muscle activity in an automobile seat with a lumbar massage system. *International journal of occupational safety and ergonomics*, *6*(1), 113-128.

Kushwaha, D. K., & Kane, P. V. (2016). Ergonomic assessment and workstation design of shipping crane cabin in steel industry. *International journal of industrial ergonomics*, *52*, 29-39.

Kwon, Y., Kim, J. W., Heo, J. H., Jeon, H. M., Choi, E. B., & Eom, G. M. (2018). The effect of sitting posture on the loads at cervico-thoracic and lumbosacral joints. *Technology and Health Care*, *26*(S1), 409-418.

Kyung, G., Nussbaum, M. A., & Babski-Reeves, K. (2008). Driver sitting comfort and discomfort (part I): Use of subjective ratings in discriminating car seats and correspondence among ratings. *International Journal of Industrial Ergonomics*, *38*(5-6), 516-525.

Kyung, G., & Nussbaum, M. A. (2008). Driver sitting comfort and discomfort (part II): Relationships with and prediction from interface pressure. *International Journal of Industrial Ergonomics*, *38*(5-6), 526-538.

Larsen, L. B., Andersson, E. E., Tranberg, R., & Ramstrand, N. 2018. Multi-site musculoskeletal pain in Swedish police: associations with discomfort from wearing mandatory equipment and prolonged sitting. *International archives of occupational and environmental health*, 91(4): 425-433.

Le, P., Rose, J., Knapik, G., & Marras, W. S. (2014). Objective classification of vehicle seat discomfort. *Ergonomics*, *57*(4), 536-544.

Lengsfeld, M., Frank, A., Van Deursen, D. L., & Griss, P. (2000). Lumbar spine curvature during office chair sitting. *Medical engineering & physics,* 22(9), 665-669.

Lipman, F. (2014). An overview of your musculoskeletal system. Retrieved from http://www.drfranklipman.com/an-overview-of-your-musculoskeletalsystem/

Ma'arof, M. I. N., & Ahmad, I. N. (2012). Proposed standard method for motorcycle nomenclature system. *2012 Southeast Asian Network of Ergonomics Societies Conference (SEANES).* doi:10.1109/seanes.2012.6299579

Ma'arof, M.I.N., Omar, A.R., Ahmad, I.N., Jaafar, R., Fauzi, W.M.S.W., Rahim, A.A., Rashid, H. & Mahmud, Z. (2015). The motorcycle design parameter database (MDPD) for different motorcycle models. *Procedia Manufacturing*, Vol. 3, pp. 2581-2588.

Ma'arof, M. I. N., Omar, A. R., Haron, R., Husain, H., & Wahab, M. A. (2017). Muscular Activities Measurements of Forward Lean and Upright Sitting Motorcycling Postures via Surface Electromyography (sEMG). In *MATEC Web of Conferences* (Vol. 135, p. 00046). EDP Sciences.

Ma'arof, M. I. N., Rashid, H., Omar, A. R., Abdullah, S. C., Ahmad, I. N., & Karim, S. A. (2014, April). THE MOTORCYCLE: A HUMAN OPERATOR INFLUENCED WORKSTATION. In *Contemporary Ergonomics and Human Factors 2014: Proceedings of the international conference on Ergonomics & Human Factors 2014, Southampton, UK, 7-10 April 2014* (p. 417). CRC Press.

Makhsous, M., Lin, F., Hendrix, R. W., Hepler, M. & Zhang, L. Q. (2003). Sitting with adjustable ischial and back supports: biomechanical changes. *Spine, 28,*1113-1121.

Manan, M. M. A., & Várhelyi, A. (2012). Motorcycle fatalities in Malaysia. *IATSS research*, *36*(1), 30-39.

Mansfield, N. J., Mackrill, J., Rimell, A. N., & MacMull, S. J. (2014). Combined effects of long-term sitting and whole-body vibration on discomfort onset for vehicle occupants. *International Scholarly Research Notices*, *2014*.

Marques, A., Stothers, L., & Macnab, A. (2010). The status of pelvic floor muscle training for women. *Canadian Urological Association Journal*, *4*(6), 419.

Martini, F. H., Nath, J. L., & Bartholomew, E. F. (2015). Fundamentals of anatomy & physiology. Pearson Education:San Francisco, CA.

Martini, F. H., Timmons, M. J., & Tallitsch, R. B. (2009).Human anatomy(6th ed.). San Francisco: PearsonBenjamin Cummings.

Matsumoto, T., Yokomori, M., Harada, N., Fukuchi, Y., Kanamori, M., & Gotoh, M. 1982. Mailmen's vibration hazards induced by motorcycle riding. Industrial health, 20(3), 167-175.

McKinnon, C. D., Amy, S. A., Callaghan, J. P., & Dickerson, C. R. (2014). The effect of police cruiser restraint cage configuration on shoulder discomfort, muscular demands, upper limb postures, and task performance during simulated police patrol. *Applied ergonomics*, *45*(6), 1414-1421.

Mehta, C., & Tewari, V. (2000). Seating discomfort for tractor operators – a critical review. *International Journal of Industrial Ergonomics,* 25(6), 661–674. doi:10.1016/s0169-8141(99)00054-2

Mergl, C., Klendauer, M., Mangen, C., & Bubb, H. 2005. Predicting long term riding comfort in cars by contact forces between human and seat (No. 2005-01-2690). SAE Technical Paper.

Mirbod, S. M., Yoshida, H., Jamali, M., Masamura, K., Inaba, R., & Iwata, H. (1997). Assessment of hand-arm vibration exposure among traffic police motorcyclists. *International Archives of occupational and Environmental health*, 70(1): 22-28.

Mirbod, S. M., Inaba, R., & Iwata, H. (1997). Subjective symptoms among motorcycling traffic policemen. *Scandinavian journal of work, environment & health,* 60-63.

Mohamad, D., Deros, B. M., Daruis, D. D., Ramli, N. F., & Sukadarin, E. H. (2016). Comfortable driver's car seat dimensions based on Malaysian anthropometrics data.

Mohamad, D., Md Deros, B., Daruis, D. D. I., Khamis, N. K., & Tahir, N. H. M. (2014). Assessment of hand-arm vibration exposure among motorcyclist in Malaysia. *In Applied Mechanics and Materials*, 663: 395-399.

Mohanty, P. P. (2014). Studies on product design using ergonomic consideration. Department of industrial design, National Institute of Technology Rourkela, India.

Mokdad, M., & Al-Ansari, M. (2009). Anthropometrics for the design of Bahraini school furniture. *International Journal of Industrial Ergonomics*, *39*(5), 728-735.

Mörl, F., & Bradl, I. (2013). Lumbar posture and muscular activity while sitting during office work. *Journal of Electromyography and Kinesiology*, *23*(2), 362-368.

Mroz, K., Östling, M., Richardsson, R., Kerrigan, J., Forman, J., & Pipkorn, B. (2020). Effect of Seat and Seat Belt Characteristics on the Lumbar Spine and Pelvis Loading of the SAFER Human Body Model in Reclined Postures. In *Proceedings of the IRCOBI Conference*.

Muzammil, M., Chandra, A., Kankar, P. K., & Kumar, H. Recent Advances in Mechanical Engineering.

Ng, D., Cassar, T., & Gross, C. M. (1995). Evaluation of an intelligent seat system. *Applied Ergonomics*, *26*(2), 109–116. https://doi.org/10.1016/0003-6870(95)00006-X

Openshaw, S. D. (2011). Predicting and quantifying seated comfort and discomfort using objective and subjective measures.

Ospina-Mateus, H., & Jiménez, L. A. Q. 2019. Understanding the impact of physical fatigue and postural comfort experienced during motorcycling: A systematic review. *Journal of Transport & Health,* 12: 290-318.

PA, I. (2020). Ergonomic Workplace Design for Micro, Small and Medium Enterprises: A Conceptual Model. *IUP Journal of Management Research*, *19*(2).

Pandey, S. W., & Somkuwar, V. An ergonomic study of wheel vehicles: a review paper. International Journal of Engineering Trends and Technology. 2017;42(1): 5-9.

Panero, J., & Zelnik, M. (1979). *Human dimension & interior space: a source book of design reference standards*. Watson-Guptill.

Patil, M. M., Bajpai, L., & Verma, P. L. (2014). Design and development of motorcycle seat from ergonomics point of view with vibration and discomfort analysis*. International Journal of Mechanical Engineering and Technology*, 5(12), 09-15.

Petersson, M., & Abbott, A. (2020). Lumbar interspinous pressure pain threshold values for healthy young men and women and the effect of prolonged fully flexed lumbar sitting posture: An observational study. *World Journal of Orthopedics*, *11*(3), 158.

Pope, M. H., Goh, K. L., & Magnusson, M. L. (2002). Spine ergonomics. *Annual review of biomedical engineering*, *4*(1), 49-68.

Porter, J. M., & Gyi, D. E. (2002). The prevalence of musculoskeletal troubles among car drivers. *Occupational medicine*, *52*(1), 4-12.

Porter, J. M., & Gyi, D. E. (1998). Exploring the optimum posture for driver comfort. International *Journal of Vehicle Design*, 19(3).

Preyde, M. (2000). Effectiveness of massage therapy for subacute low-back pain: a randomized controlled trial. *Cmaj*, *162*(13), 1815-1820.

Pynt, J., Higgs, J., & Mackey, M. (2001). Seeking the optimal posture of the seated lumbar spine. *Physiotherapy theory and practice*, *17*(1), 5-21.

Ramasamy, S., Adalarasu, K., & Trupti, N. P. 2017. Evaluation of driving-related musculoskeletal disorders in motorbike riders using Quick Exposure Check (QEC).

Ranger, T. A., Teichtahl, A. J., Cicuttini, F. M., Wang, Y., Wluka, A. E., O'Sullivan, R., ... & Urquhart, D. M. (2016). Shorter lumbar paraspinal fascia is associated with high intensity low back pain and disability. *Spine*, *41*(8), E489-E493.

Rashid, H., Omar, A. R., Mahmud, Z., & Fauzi, W. M. S. W. (2021). Musculoskeletal Disorders (MSDs) among Non-Occupational

Motorcyclists: What are the issues?. Asian Journal of University Education, 16(4), 220-229.

Rashid, H., Omar, A. R., Ahmad, I. N., Mohamed, Z., Wan Fauzi, W. M. S., Mahmud, Z., & Haron, R. (2017). Motorcyclists' prolonged riding simulation: the setup and procedures. *Journal of Mechanical Engineering (JMechE)*, (5), 197-208.

Rashid, H., Ma'arof, M. I. N., Omar, A. R., Abdullah, S. C., & Jaafar, R. (2014). Evolution of a New Adjustable Motorcycle Test Rig for Measuring Motorcyclist Fatigue during Prolonged Riding. *Advances in Human Aspects of Transportation*, (Part II), 3.

Road and Transport Department. (2016). Malaysia. Retrieved from http://www.jpj.gov.my/web/guest/pendaftaran-kenderaan-perdagangan

Romanowski, M. W., Špiritović, M., Rutkowski, R., Dudek, A., Samborski, W., & Straburzyńska-Lupa, A. (2017). Comparison of deep tissue massage and therapeutic massage for lower back pain, disease activity, and functional capacity of ankylosing spondylitis patients: a randomized clinical pilot study. *Evidence-Based Complementary and Alternative Medicine*, *2017*.

Roscoe. (2017). Mending, coaching, & inspiring athlete. Retrieved from https://sbrsport.me/2017/03/13/the-center-of-movement-thoracolumbar-fascia/

Roseiro, L. M., Neto, M. A., Amaro, A. M., Alcobia, C. J., & Paulino, M. F. 2016. Hand-arm and whole-body vibrations induced in cross motorcycle and bicycle drivers. International Journal of Industrial Ergonomics, 56: 150-160.

Rufa'i, A. A., Sa'idu, I. I. A., Ahmad, R. I. Y., Elmi, O. S., Aliyu, S. U., Jajere, A. M., & Digil, A. A. (2015). Prevalence and risk factors for low back pain among professional drivers in Kano, Nigeria. *Archives of environmental & occupational health*, *70*(5), 251-255.

Sammonds, G. M., Fray, M., & Mansfield, N. J. (2017). Effect of long term driving on driver discomfort and its relationship with seat fidgets and movements (SFMs). *Applied ergonomics*, *58*, 119-127.

Said, M. K. N., Ma'arof, M. I. N., Rashid, H., Ahmad, I. N., Fauzi, W. M. S. W., Omar, A. R. & Jaafar, R. (2015). Motorcyclists Vs Car Drivers: Quantifying the magnitude of vehicular discomforts experienced between operating a motorcycle and a car. *Jurnal Teknologi, 76*(11).

Savonnet, L., Wang, X., & Duprey, S. (2018). Finite element models of the thigh-buttock complex for assessing static sitting discomfort and pressure sore risk: a literature review. *Computer Methods in Biomechanics and Biomedical Engineering, 21(4), 379–388.* doi:10.1080/10255842.2018.1466117

Shafiei, U. K. M., Karuppiah, K., Tamrin, S. B. M., Meng, G. Y., Rasdi, I., & Alias, A. N. (2015). The effectiveness of new model of motorcycle seat with built-in lumbar support. Jurnal Teknologi, 77(27).

Shahar, A., Poulter, D., Clarke, D., & Crundall, D. (2010). Motorcyclists' and car drivers' responses to hazards. *Transportation research part F: traffic psychology and behaviour*, *13*(4), 243-254.

Shende, V. (2014). Analysis of research in consumer behavior of automobile passenger car customer. *International Journal of Scientific and Research Publications, 4*(2), 1.

Shivakumara, B. S., & Sridhar, V. 2010. Study of vibration and its effect on health of the motorcycle rider. online Journal of health and allied sciences, 9(2).

Shoemaker, J. K., Tiidus, P. M., & Mader, R. (1997). Failure of manual massage to alter limb blood flow: measures by Doppler ultrasound. *Medicine and science in sports and exercise*, *29*(5), 610-614.

Smith, D. R., Andrews, D. M., & Wawrow, P. T. (2006). Development and evaluation of the automotive seating discomfort questionnaire (ASDQ). *International Journal of Industrial Ergonomics*, *36*(2), 141-149.

Smith, L.L., Keating, M.N., Holbert, D., Spratt, D.J., Mccammon, M.R., Smith, S.S. & Israel, R.G. (1994). The effects of athletic massage on delayed onset muscle soreness, creatine kinase, and neutrophil count: a preliminary report. *Journal of Orthopaedic and Sports Physical Therapy, 19*,93 – 99.

Sobeih,Y., Salem, O.,Genaidy, A., Abdelhamid, T. & Shell, R. (2009). Psychosocial factors and musculoskeletal disorders in the construction industry. *Journal of Construction Engineering and Management*, *135(*4):267-277.

Social Security Organization (SOCSO): Annual Report. (2018). Ministry of Human Resources, Malaysia. Retrieved from https://www.perkeso.gov.my/images/laporan_tahunan/LAPORAN%20TAHUNAN%20_ANNUAL%20REPORT%202018.pdf

Speed, G., Harris, K., & Keegel, T. (2018). The effect of cushioning materials on musculoskeletal discomfort and fatigue during prolonged standing at work: A systematic review. *Applied ergonomics*, *70*, 300-314.

Sturgeon, T. J., Memedovic, O., Van Biesebroeck, J., & Gereffi, G. (2009). Globalisation of the automotive industry: main features and trends. International Journal of Technological learning, innovation and development, 2(1-2), 7-24.

Sudoł-Szopińska, I., Bogdan, A., Szopiński, T., Panorska, A. K., & Kołodziejczak, M. (2011). Prevalence of Chronic Venous Disorders Among Employees Working in Prolonged Sitting and Standing Postures. *International*

Journal of Occupational Safety and Ergonomics, 17(2), 165–173. doi:10.1080/10803548.2011.11076887

Tanaka, T. H., Leisman, G., Mori, H., & Nishijo, K. (2002). The effect of massage on localised lumbar muscle fatigue. *BMC complementary and alternative medicine*, *2*(1), 1-8.

Tang, C. Y., Chan, W., & Tsui, C. P. (2010). Finite element analysis of contact pressures between seat cushion and human buttock-thigh tissue. *Engineering*, *2*(09), 720.

Tatsuno, J., Suyama, K., Nakamura, H., & Maeda, S. (2020, July). Detection and Classification of Unconscious Movements with Body Pressure Distribution Measurement for Ride Comfort Evaluation in Vehicle Seat. In International Conference on Applied Human Factors and Ergonomics (pp. 276-282). Springer, Cham.

The Official Portal of Royal Malaysia Police. (2015). *Mengenai Polis Diraja Malaysia*. Retrieved from http://www.rmp.gov.my/infor-korporate/polis-diraja-malaysia.

Thomas Jr, R. E., Congleton, J. J., Huchingson, R. D., Whiteley, J. R., & Rodrigues, C. C. (1991). An investigation of relationships between driver comfort, performance and automobile seat type during short term driving tasks. *International journal of industrial ergonomics*, *8*(1), 103-114.

Van Nieuwenhuyse, A., Fatkhutdinova, L., Verbeke, G., Pirenne, D., Johannik, K., Somville, P. R., ... & Masschelein, R. (2004). Risk factors for first-ever low back pain among workers in their first employment. *Occupational Medicine*, *54*(8), 513-519

.

Van Poppel, M. N., Hooftman, W. E., & Koes, B. W. (2004). An update of a systematic review of controlled clinical trials on the primary prevention of back pain at the workplace. *Occupational Medicine*, *54*(5), 345-352.

Velagapudi, S. P., Balasubramanian, V., Adalarasu, K., & Mangraju, V. (2010). Muscle fatigue due to motorcycle riding*. Contemporary Ergonomics and Human Factors 2014: Proceedings of the international conference on Ergonomics & Human Factors 2014*. CRC Press: UK.

Velagapudi, S. P., & Ray, G. G. (2017). Development of a Seating Comfort Questionnaire for Motorcycles. *Human Factors*, *59*(8), 1249–1262. https://doi.org/10.1177/0018720817735929

Velagapudi, S. P., Balasubramanian, V., Adalarasu, K., Babu, R. & Mangaraju, V. (2010). Muscle fatigue due to motorcycle riding. *SAE Technical Papers.* doi:10.4271/2010-32-0100

.

Verver, M. M., Van Hoof, J., Oomens, C. W. J., Wismans, J. S. H. M., & Baaijens, F. P. T. (2004). A finite element model of the human buttocks for

prediction of seat pressure distributions. *Computer methods in biomechanics and biomedical engineering*, *7*(4), 193-203.

Vink, P., Koningsveld, E. A., & Molenbroek, J. F. (2006). Positive outcomes of participatory ergonomics in terms of greater comfort and higher productivity. Applied ergonomics, 37(4), 537-546.

Vink, P., & Hallbeck, S. (2012). *Comfort and discomfort studies demonstrate the need for a new model*. Elsevier.

Waongenngarm, P., van der Beek, A. J., Akkarakittichoke, N., & Janwantanakul, P. (2020). Perceived musculoskeletal discomfort and its association with postural shifts during 4-h prolonged sitting in office workers. *Applied Ergonomics*, *89*, 103225.

Wang, M., Yu, J., Liu, N., Liu, Z., Wei, X., Yan, F., & Yu, S. (2017). Low back pain among taxi drivers: a cross-sectional study. *Occupational Medicine*, *67*(4), 290-295.

Wilke, J., Schleip, R., Klingler, W., & Stecco, C. (2017). The lumbodorsal fascia as a potential source of low back pain: a narrative review. *BioMed research international*, *2017*.

Yusof, N. A. D. B. M. (2016). Risk to Work-Related Musculoskeletal Disorders among Traffic Police Riders. Universiti Putra Malaysia, Malaysia.

Yusuff, R. M. (2016). Development of an anthropometry database for the malaysian population: problems and challenges. *Malaysian Journal of Public Health Medicine*, *16*(Supplement 2), 36-43.

Zhang, L., Helander, M. G., & Drury, C. G. (1996). Identifying factors of comfort and discomfort in sitting. *Human factors*, 38(3): 377-389.

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Nur Athirah Diyana bt Mohammad Yusof is a PhD student in Occupational Safety and Health. Her research focuses on occupational health in motorcycle ergonomic. She received a Master of Science (Occupational Safety & Health) in Universiti Putra Malaysia, 2017, with a thesis that analysed the risk factors of musculoskeletal disorders among traffic police riders in Malaysia. She actively participated in competition and conference throughout being a PhD student. She had won a Gold Award entitled 'Development of Lumbar Support for Motorcycle Seat with Built-In Massager System: Traffic Police Riders' in Research Innovation Poster Competition Series 1/2021 and 2nd Prize in Road Safety Infographic Poster Competition in 2019 organised by The Institute of Engineer Malaysia. She also had participated and presented in the 4th International Conference on Ergonomics & 2nd International Conference on Industrial Engineering, 2019. She had listed as an Ergonomic Trained Person (Initial Ergonomic Risk Assessment) in 2021. So far, she had published (authored & co-authored) 16 scientific papers, including five papers in high impact journals. She also becomes a reviewer for the Malaysian Journal of Medicine and Health Sciences in 2020 and 2021. Her scientific research interests include occupational exposure, ergonomics, musculoskeletal disorders, air pollutants, occupational safety and health.

LIST OF PUBLICATIONS

Nur Athirah Diyana Mohammad Yusof, Karmegam Karuppiah, Putri Anis Syahira Mohamad Jamil, Irniza Rasdi, Vivien How, Sivasankar Sambasivam. Development and Initial Testing of Lumbar Support for Traffic Police Motorcycle Seat With Built-In Massager System: A Preliminary Study In The View of Ergonomics. *4th IEOM European International Conference on Industrial Engineering and Operations Management*. August 2-5, 2021 [Accepted].

Mohammad Yusof, N. A. D., Karupiah, K., Mohd Tamrin, S. B., Rasdi, I., How, V., Sambasivam, S., ... & Mohd Suadi Nata, D. H. (2021). Effectiveness of lumbar support with built-in massager system on spinal angle profiles among high-powered traffic police motorcycle riders: A randomised controlled trial. *PLoS one,* 16(10), e0258796.

Nur Athirah D, Karmegam K, Irniza R, Shamsul Bahri MT, Vivien H, Putri Anis S, Kulanthayan K. C. Mani, Sivasankar S, & Mohd Hafzi MI. (2020). High-Powered Police Motorcycle: Muscle Discomfort Among Malaysian Traffic Police Riders. *Malaysian Journal of Public Health Medicine,* 20(Special1), 255-259.

Diyana, M.A., Karmegam, K., Shamsul, B.M.T., Irniza, R., Vivien, H., Sivasankar, S., Syahira, M.P.A. and Kulanthayan, K.C.M. (2019). Risk factors analysis: Work-related musculoskeletal disorders among male traffic policemen using high-powered motorcycles. *International Journal of Industrial Ergonomics,* 74, 102863.

Nur Athirah Diyana Mohammad Yusof, Putri Anis Syahira Mohamad Jamil, Nurul Maizura Hashim, Karmegam Karuppiah, Irniza Rasdi, Shamsul Bahri Mohd Tamrin, Vivien How, Sivasankar Sambasivam. Likert Scale vs. Visual Analogue Scale on Vehicle Seat Discomfort Questionnaire: A Review. (2019). *Malaysian Journal of Public Health Medicine*, 15(SP4): 159-164, Dec 2019

Diyana, N. A., Karuppiah, K., Rasdi, I., Vivien, H., Shamsul B. M. T., Sivasankar, S., & Hafzi M. I. (2019). A Review: Muscle Discomfort of Police Officers in Vehicles. *Malaysian Journal of Medicine and Health Sciences* Vol.15 Supp 3, Aug 2019 (eISSN 2636-9346)

Diyana, N. A., Karuppiah, K., Rasdi, I., Sambasivam, S., Tamrin, S. B. M., Mani, K. K., & Azmi, I. (2017). Vibration exposure and work-musculoskeletal disorders among traffic police riders in Malaysia: A review*. Annals of Tropical Medicine and Public Health,* 10(2), 334.

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